

Picosecond Response, Recirculating Optical Probe for Encoding Radiation (ROPER)



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LLNL is performing physics experiments on the NIF, OMEGA and Phoenix platforms, including those addressing deuterium-tritium (DT) burn physics, equations of state, and dynamic material properties. The dynamic range, spatial resolution, bandwidth, and noise-robustness required in these experiments are extremely challenging and surpass present capabilities. This project is undertaking engineering reduction to practice of a picosecond response time, radiation to optical down-converting detector that can address these requirements.

The Picosecond Response, Recirculating Optical Probe for Encoding Radiation (ROPER) sensor is a resonant optical cavity consisting of high-reflectance mirrors that surround a direct band-gap semiconductor detection medium (Figs. 1 and 2). Radiation absorption within the detection medium induces a change in its optical refractive index. The index change is detected with an optical probe. The perturbation in the refractive index modulates the phase of the probe beam. Interferometry is used to convert the phase modulation to amplitude modulation, down-converting the radiation signature to the optical domain.

The sensor architecture can be optimized for detection of γ rays, x rays and neutrons. We project that integration of these sensors with advanced optical data recorders offers the possibility of probing the DT burn rate with good detection sensitivity (4×10^3 g/cm²) and \sim ps temporal resolution.

Project Goals

At the end of the project we hope to successfully demonstrate a fully characterized, optimized, prototype, high-bandwidth, x-ray sensor, and provide a plan for integrating the sensor with a next-generation optical recorder, to address the possibility of creating an \sim ps response, γ detector for Weapons Complex Integration (WCI) experiments on NIF.

Relevance to LLNL Mission

This project specifically addresses the instrumentation requirements of WCI. It is well aligned with LLNL engineering focus areas and enhances LLNL's core competency in measurement science at extreme dimensions. We anticipate that, when available, ICF and HEDS experimental programs, and NIF will identify applications for these detectors.

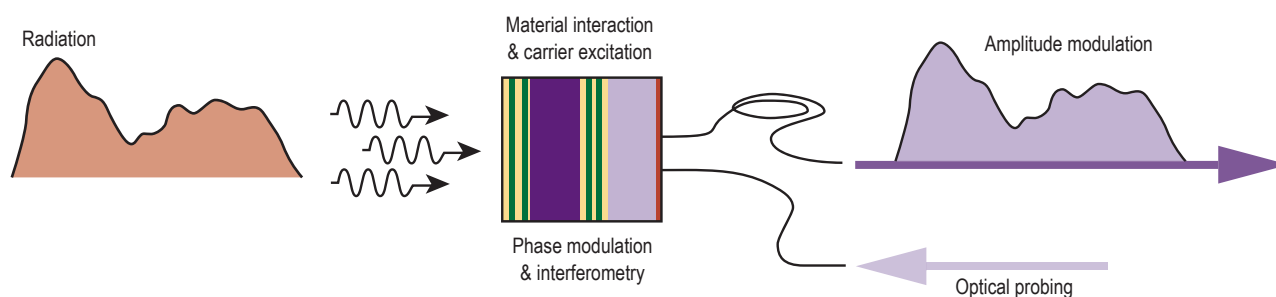


Figure 1. The ROPER system. Radiation absorption within the ROPER sensor modifies the sensor optical properties. Interferometric detection of the phase-modulated probe beam converts the radiation signature to an amplitude-modulated optical signal.

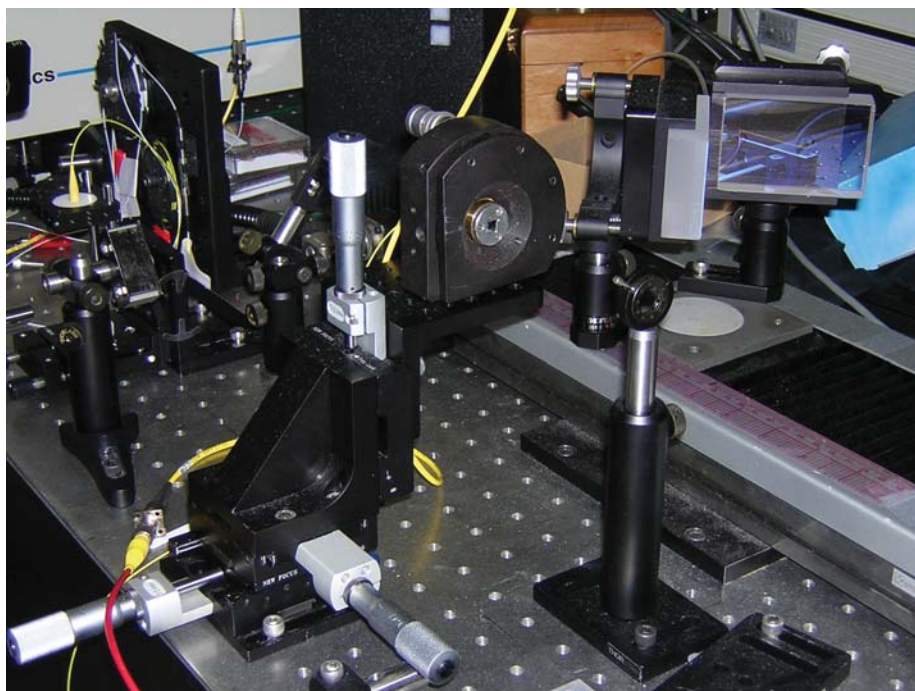


Figure 2. Fiber-based ROPER, pump-probe, optical testbed. A Ti:sapphire pump laser (140-fs pulse duration at 800 nm) is used as a surrogate excitation source and 1550-nm CW fiber-coupled probe is used for readout. The sensor is mounted on the translation stage at the top center of the figure.

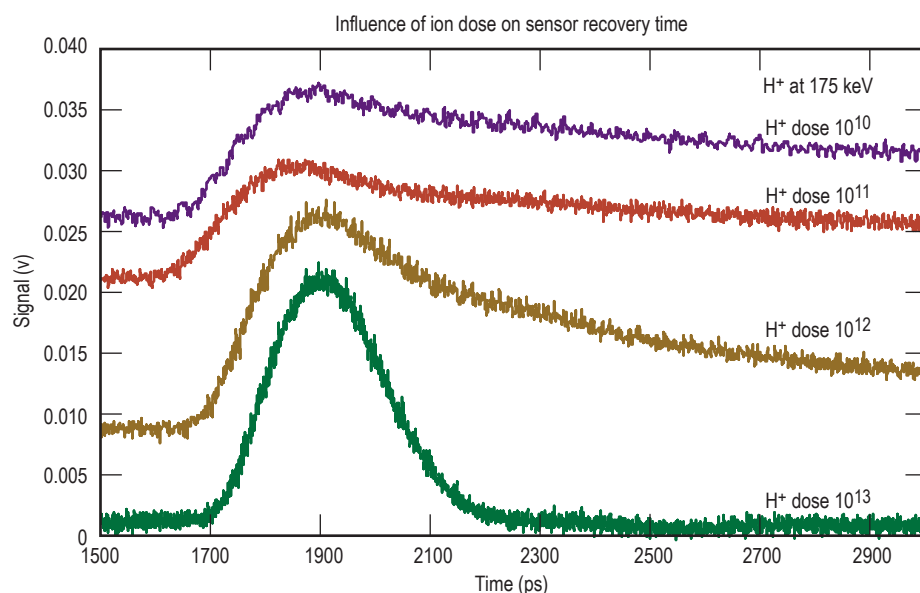


Figure 3. Sensor characterization. Radiation damage (H^+ ion implantation) is used to tailor the sensor response time. Note that the sensor recovery time varies from 10 ns to 100 ps as the H^+ dose is increased from 10^{10} (purple curve) to 10^{13} (green curve) ions/cm².

FY2007 Accomplishments and Results

Pump-probe optical testbeds with both free-space and fiber optical systems were implemented for sensor characterization. High finesse ($f \sim 20$) Fabry-Perot sensors, operating at or near 1550 nm, using radiation damaged $In_xGa_{1-x}As_yP_{1-y}$ sensor material were fabricated and characterized. Proton ion, H^+ , implantation was used to tailor the carrier recombination time in the sensor medium and, therefore the temporal response of the detector (Fig. 3). Measurements made with 140-fs pulse duration, 800-nm Ti:sapphire excitation, and a 1550-nm CW probe show that sensor bandwidth can be tuned with ion dose. For H^+ at 175 keV and $10^{13}/cm^2$, an instrument-limited sensor temporal response of ~ 100 ps is observed.

Current engineering efforts are focused on improving the fidelity and S/N in pump-probe characterization of radiation damaged sensors using 800-nm Ti:sapphire excitation and a spectrally filtered slave optical parameter amplifier at 1550 nm.

Related References

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2. Bennett, C. V., and B. H. Kolner, *IEEE J. Quant. Electr.*, **36**, pp. 430-437, 2000.
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FY2008 Proposed Work

In FY2008 optimized ROPER sensors will be engineered for integration with an advanced optical recorder. Our goal is demonstration of a working "front-end" for a high-bandwidth x-ray detection system. In parallel, we will work on an implementation plan for integrating the ROPER sensor and a recording system to address the possibility of implementing an \sim ps response γ detector for WCI experiments at NIF.